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مطالعه آشکارساز فوتونی فرابنفش بر پایه آرایه های نانوسیم اکسید روی

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چکیده - ساخت و مشخصه یابی آشکارساز فوتونی فرابنفش آرایه های نانوسیم اکسید روی در این مقاله ارائه شده است. ساختار نانویی که شامل نانوسیم های مرتب بر زیرلایه شیشه ای هستند از طریق رسوب گذاری حمام شیمیایی به دست آمده اند. ویژگی های مورفولوژی، ساختاری و اپتیکی این نانوساختارها بررسی شده اند. نانوسیم های به دست آمده ساختار ورزیت دارند و در راستای ترجیحی [0001] عمود بر زیرلایه رشد کرده اند. این نتایج از تصویر میکروسکوپ الکترونی روبشی گسیل میدانی (*FESEM*) و نقش پراش پرتو ایکس (*XRD*) استخراج شده اند. ویژگی های اپتیکی لایه نازک *ZnO* به وسیله طیف فرابنفش-مرئی و طیف فوتولومینسانس(*PL*) بررسی شده است. ویژگی های الکتریکی به دست آمده از منحنی جریان-ولتاژ، یک فوتورسانا با اتصالات اهمی تحت روشنایی و جریان تاریکی پایین و سرعت پاسخ *mA/W* 0/83 را نشان می دهند.

کلید واژه- آشکارساز فرابنفش، نانوسیم های اکسید روی، رسوب گذاری حمام شیمیایی، ویژگی های ساختاری، ویژگی های اپتیکی، ویژگی های الکتریکی

Study of ultraviolet Photodetectors based on ZnO nanowires

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Abstract- The fabrication and characterization of a ZnO nanowired arrays ultraviolet photodetector (ZnO NW arrays PD) has been presented. The nanostructures used included well-aligned Nanowires on glass substrate by chemical bath deposition (CBD). The morphological, structural, and optical properties of these nanostructures were investigated. The obtained ZnO NWs had a wurtzite structure and grew along the preferential [0001] orientation with a normal direction to the substrate. This results have been investigated by field emission scanning electron microscopy (FESEM) image and X-ray diffraction (XRD) pattern. The optical properties of the ZnO thin film have been investigated by UV-Visible spectroscopy and photoluminescence spectroscopy (PL).The electrical properties which is investigated from current-voltage curve show a photoconductor with an ohmic contact under illumination, and the low dark current and 0.83 mA/W as the responsivity of a photoconductor.

Keywords: UV detector, ZnO nanowires, Chemical bath deposition, Structural properties, Optical properties, Electrical properties

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Study of ultraviolet Photodetectors based on ZnO nanowire arrays

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1 Introduction

Bio-safe, multi-functional ZnO is one of the most important II–VI semiconductor materials with a wide direct band gap of 3.37 eV [1]. Many researchers are trying to explore the low-cost, environment friendly and wide band gap (~3.34 eV) zinc oxide (ZnO) material with large exciton energy (~60 meV) for the UV detection applications [2]. Within the diversified morphologies of ZnO nanostructures, the one dimensional (1D) structures are fundamentally the most exciting ones due to their potential for direct utilization in device fabrication [3]. Because of their unique physical and chemical properties, integrating 1D nanostructures into two or three-dimensions (as "thin film" or "supperlattice") is an extra-ordinarily important task towards the realization of the functional nanodevices [4,5]. 1D ZnO nanostructures have been fabricated using various methods including thermal evaporation, thermal chemical vapor deposition, metalorganic chemical vapor deposition, sol–gel process [6] and chemical bath deposition. Among these techniques, the chemical bath deposition is an inexpensive technology for ZnO thin films production [7].

In this work we present a UV PD based on the ZnO NW arrays fabricated by chemical bath deposition (CBD) on the glass substrate.

2 Materials and method

2.1 Preparation of the ZnO seed layers

Thin seed film of zinc oxide has been prepared by thermally decomposing zinc acetate on glass substrate. 8 mM solution of zinc acetate dihydrate ($Zn(OOCCH)_3$-$2H_2O$) in pure ethanol are produced. The washed substrate were initially placed in ethanol solution and then placed in a furnace for few minutes.

2.2. Preparation of the ZnO NW arrays

Chemical bath deposition approach was used to fabricate the vertically aligned ZnO nanowire array films. In this synthesis, amorphous glass substrate functionalized with ZnO seed film was kept in the 16 mM aqueous solution of zinc nitrate ($Zn(NO_3)_2.6H_2O$) and 16 mM of hexamine (HTMA) ($C_6H_{12}N_4$) for 3:30 h. The nanowire grown substrate is taken out and rinsed with deionized (DI) water and dried in laboratory oven at 400° C for 1 h.

The morphology and structure of the ZnO nanowireds were characterized by field emission scanning electron microscopy (FESEM) and X-ray diffraction (XRD) using monochromatic Cu K_α radiation (λ=1.54 Å). The UV-vis absorption measurement used forstudy of optical properties.

3 Results and Discussion

The FESEM image in Fig.1 clearly reveals the obtained ZnO nanowireds with hexagonal shapes, smooth surfaces, and a uniform diameter along their entire lengths. In addition, the ZnO nanowireds have high-growth distribution density on the glass substrate, which is related to the good homogeneity of the seed layer. The average diameter of ZnO nanowireds obtained from the corresponding FESEM images are ~ 80 nm.

Fig. 2 shows the XRD patterns of ZnO NWs grown by CBD on seeded amorphous glass substrate. All the diffraction peaks can be indexed

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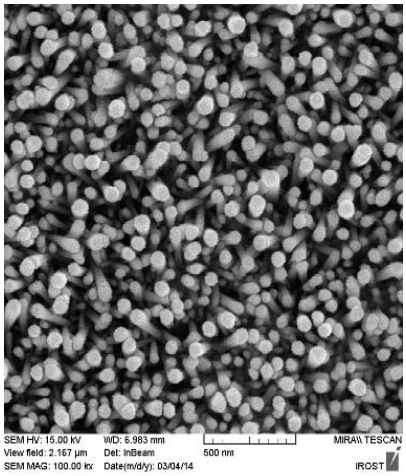


Fig. 1: FESEM images of ZnO NWs annealed at 400°C.

hexagonal wurtzite (space group P63mc) ZnO agree well with 01-075-0576 of the standard XRD pattern. No other peaks related to any defects were observed in these XRD patterns indicating that the ZnO nanocrystals is of high purity. The XRD pattern shows the XRD peaks due to (100), (002), (101) of ZnO. The (002) diffraction peak, indicating the preferential growth in the c-axis

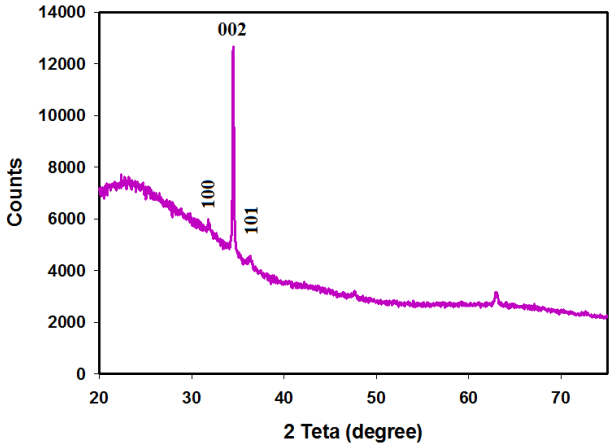


Fig. 2: XRD spectra of ZnO NWs grown through CBD on glass seeded substrate.

direction. XRD patterns of the resulting NW arrays demonstrate that the orientation of the ZnO seeds directly determines the orientation of the NWs [8]. So, we can calculated the ZnO seed layer has the same orientation. The average crystallite size of the ZnO nanostructures along the (002) peak is obtained by the following Scherrer equation [9]:

$$D = 0.9\lambda/(\beta\cos\theta)$$

Where D, θ, λ, and β represent the average crystallite size, Bragg diffraction angle, X-ray radiation wavelength, and full width at half maximum value, respectively. The average crystallite size of ZnO thin film is 74.72 nm.

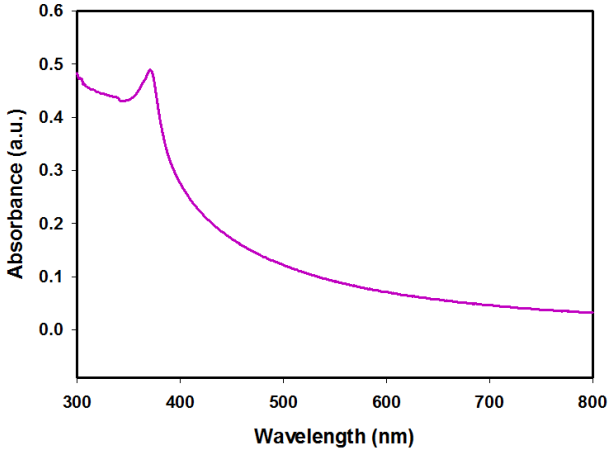


Fig. 3: UV-visible absorption spectra of ZnO NWs

The UV-vis absorption spectrum of the synthesized ZnO (Fig. 3) gave a strong excitonic absorption band at 371.3 nm. Compared to UV-vis absorption spectrum of bulk ZnO (375 nm), it is blue shifted (3.7 nm). The blue shift of the absorption band is unusual and can be described as the very thin bridge between the synthesized nanoparticles, some of which had a diameter approaching Bohr radius. The similar results have also been reported previously by Li et al. [11] and Bai et al [12].

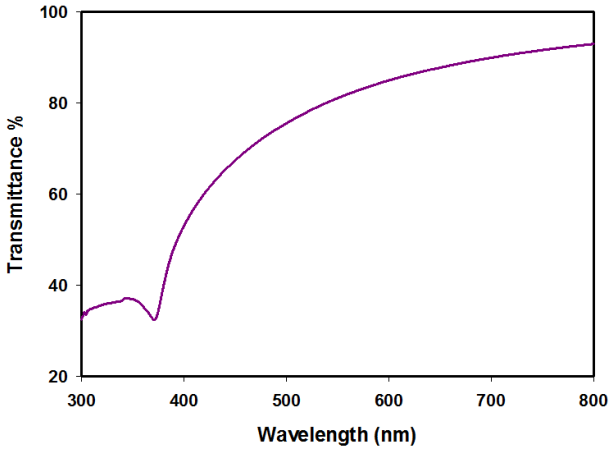


Fig. 4: The optical transmittance spectra of ZnO NWs grown on glass substrate.

In Figure 4 it is shown that the transmission of ZnO film is high over large wavelengths. ZnO film exhibits a relatively high average transmittance (~70%) in the visible region. This suggests that the produced film indicates a good optical quality due to low scatter or absorption losses.

PL measurement (Fig. 5) shows three emission peaks. Peak 1 is observed at 381 nm, and the wavelengths correspond to 3.25 eV band gap energy of ZnO. This UV peak is attributed to free excitonic band-edge recombination. The peak 2 at 406 nm is caused by the presence of zinc vacancy

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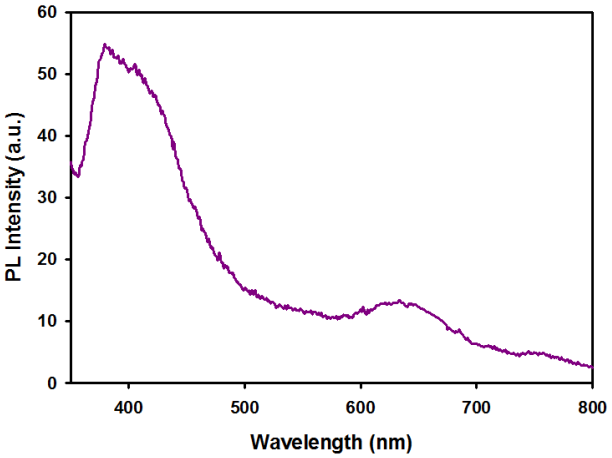


Fig. 5:.Room temperature PL spectra of ZnO NWs grown on glass seeded substrate.

related defect states on the surface of the NWs [13]. A broad visible band emission (peak 3) around 630 nm may related to structural defects [14]. While compared with the sharp UV emission, the weak emission in visible region is almost negligible, which can account for the formation of the high crystal quality ZnO NW arrays [12].

4 UV photodetector fabrication and characterization

To fabricate the UV photodetector, we applied two 102 nm-thick-Au electrodes were deposited onto the two sides of the Zno layer and served as contacts. The Au electrodes were 12 mm long with 10.5 mm spacing. Finally, two copper wires were attached on the surface of the Au electrodes using silver conductive adhesive.

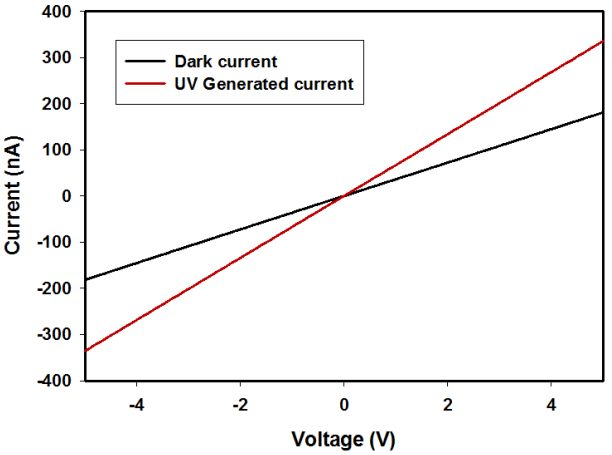


Fig. 6: I–V plot of ZnO NWs PD in dark and under UV light illumination.

The current–voltage (I–V) were measured at room temperature in the dark and under illuminated conditions at 397 nm with a 401 µW incident optical power. The I-V measurement is performed using Agilent 414HB semiconductor parameter analyzer, at room temperature. As seen in Fig.6, shows a linear I–V response and the UV generated current to dark current ratio. It clearly indicates that the value of the current at a given voltage under illumination is higher than dark indicating an enhancement in carrier concentration. Also, by reducing the distance between two electrodes, the conductivity of the NW arrays under illumination of the UV light with compare to the conductivity in the dark will be increase. One can also measure the response of device from the figure. As we increased the biasing voltage, the responsivity is also increased [15]. Under a 5 V bias applied the photoresponse is 0.83 mA/W.

5 Conclusion

In summary, we have demonstrated that ZnO NW arrays can be synthesized using the CBD method with using ZnO seed layer. We presented CBD is a valuable approach to grow ZnO NW arrays on the glass seeded substrate. UV-visible absorption spectroscopy and room temperature PL measurement exhibited ZnO NW arrays are sensitive to UV light. So, we show that this approach is suitable for fabrication a low-cost ultraviolet photodetector.

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